Universitätsklinik Balgrist
Klinik für Anästhesie, Intensivmedizin und Schmerztherapie
Chefarzt: PD Dr. med. Urs Eichenberger

Arbeit unter der Leitung von Dr. med. José A. Aguirre, MSc

Deltoid, triceps, or both response improve the success rate of the interscalene catheter surgical block compared with the biceps response

INAUGURAL-DISSERTATION
zur Erlangung der Doktorwürde der Humanmedizin
an der Medizinischen Fakultät
der Universität Zürich

vorgelegt von
Sandra Esther Guzzella

Genehmigt auf Antrag durch Prof. Dr. med. Alain Borgeat
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Publikationshinweis

Deltoid, triceps, or both responses improve the success rate of the interscalene catheter surgical block compared with the biceps response.

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I SUMMARY

Background and Objective: Interscalene regional anesthesia is a well-recognised efficient technique to control pain during and after major shoulder surgery. There are two main techniques to place the local anesthetic into the desired place: the well reliable electro stimulation and the newer ultrasound techniques. The former uses elicitation of muscle response to navigate the needle to its desired location. For a long time, a muscle response below the shoulder level was considered sufficient. Recent studies investigating the success rate in the neighbouring infraclavicular block showed a relation between the type of muscular response and the overall performance of the block.

They all demonstrated that a stimulation of the posterior cord-radial-type was associated with higher success rate compared to stimulation of the median or lateral cord.

Although the clinical daily routine point into the same direction regarding the interscalene block, to our best knowledge, there are no studies until now, investigating this relation for the interscalene site.

Therefore we conducted a double-blind investigation, to compare the success rate of ISC after biceps (group B) or deltoid and/or triceps (group DT) muscular response.

Methods: 300 (ASA I-II) patients for elective arthroscopic rotator cuff repair were prospectively randomized to B-group or DT-group. All interscalene catheters were placed with the aid of neurostimulation. The tip of the stimulating needle was first placed to trigger a muscle response as defined by the study group of either biceps (B-group) or deltoid and/or triceps (DT-group). Then the current was reduced until a disappearance of muscular twitches at exactly 0.3mA with an impulse duration of 0.1ms and 2Hz was reached. The catheter was threaded 2-3cm past the tip of the stimulating needle and the block was performed with 40ml Ropivacaine 0.5% through the interscalene catheter. A successful block was defined as sensory block of the supraclavicular nerves and sensory and motor block involving the axillary, radial, median and musculocutaneous nerves within 30min. The need of supplementary analgesics intraoperatively was considered as failure.

Results: Demographic and surgical data were similar in both groups. The success rate was 98.6% in the DT-group versus 92.5% in the B-group ($p<0.05$). Supplementary analgesics during handling of the posterior part of the shoulder capsule were needed in 2 DT-group patients and in 7 B-group patients. In the B-group, 3 patients had an incomplete radial nerve distribution anesthesia, causing the necessity of general anesthesia. One patient in the B-group had an isolated incomplete posterior block extension of the supraclavicular nerve. No acute (CNS-intoxication, cardiac toxicity) or late complications (infection, neuropathy after 30 days) were observed in both groups.

Conclusion: The elicitation of deltoid and/or triceps twitches was associated with a higher success rate compared to biceps response when performing an intrascalene catheter.

II INTRODUCTION

Since its first description in 1946, continuous peripheral nerve block (cPNB) has evolved from being a case report of a needle inserted through a cork taped onto a patient's chest to an integral part of pain control management in the postoperative period.[1, 2] In comparison to opioid analgesic, cPNB provide superior analgesia due to reduced opioid-induced side effects like nausea, vomiting, pruritus and sedation as well as a decrease in sleep disturbance. Further more, a higher patient satisfaction is obtained when comparing the two methods.[3]

Orthopedic surgery constitutes the major indication for cPNB due to its severe pain creation, which exceeds most other perioperative settings.[4, 5] These procedures entail massive nociceptive input from the richly innervated joint tissue, producing continuous deep somatic pain and bursts of reflex spasm of muscles supplied by the same and adjacent spinal cord segments innervating the operative site.[6] Furthermore, in the periarticular structures are not only C afferents represented, but also A-α and A-δ afferents.[7] These two nociceptors differ greatly in structure (C fibers being unmyelinated) as well as in the sensation they are producing. C fibers continue firing when under a constant stimulus, producing a burning pain sensation. A-δ afferents on the contrary decrease or cease firing upon an ongoing stimulus (such as a postoperative wound), producing a short lasting piercing pain. However, if the wound site is restimulated by movement (during physiotherapy, dress changing or coughing), these fibers are easily reactivated and can cause great discomfort and hindrance during the early postoperative phase since they are being poorly blocked by opioids.[8]

Contrary to that, cPNB not only reduces the immediate experienced postsurgical pain, but there is also some evidence that thereby the risk of a pain chronification can be decreased.[9, 10]

Furthermore it deserves mention that these favorable features are mostly achieved without a significantly higher claim of time. For example, the mean time required from the beginning of anesthesia to the incision by the surgeon was shown to be 25 minutes in patients undergoing general anesthesia versus 28 minutes in patients receiving an interscalene block.[11]

Among all joints, the shoulder exhibits the greatest range of motion. Therefore it shows less stability and is prone to lesions, resulting often in a need for operative reconstruction. Pain after shoulder surgery is severe, particularly after rotator cuff repair.[12, 13]

The interscalene catheter is standard for the treatment of postoperative pain in this condition.[14] This technique allows early and efficient rehabilitation,[15] decreases side-effects [16] and improves patient satisfaction.[17]

This work will focus on the cPNB used in our trial: the interscalene catheter.

The insertion techniques are based upon the same basic rules as all the cPNB: In skin preparations sterility is of utmost importance. For needle choice short bevel needles are widely accepted as standard practice.

For nerve localization in the onset, PNB were performed using induced paresthesia ("no paresthesia and no analgesia").[18]

Since its introduction nerve stimulation has been considered the gold standard. The basic principle thereby being the placement of an insulated needle close to a peripheral nerve to using electrical current to determine the distance to the nerve.[19] Doing so it is of upmost importance to guide the needle tangentially to the nerve, to avoid nerve injury. Once the elicited motor response indicates a close enough and proper placement, injection of local anaesthetic or the insertion of a catheter is performed. When used properly, nerve stimulation has a high success rate.

The usage of ultrasound for catheter placement presents another technique of nerve localization. Due to the magnitude of this topic alone, this work will focus on the catheter placement by electro stimulation only.

As for the local anaesthetics, Bupivacaine and Ropivacaine are the most commonly used, both belonging to the amino group and providing adequate analgesia without major toxicity. How ever Ropivacaine is reported to be the more motor sparing and less cardiotoxic of these two.[20, 21]

Concerning the basal rate, bolus volume and lock-out period at the moment there is insufficient information available to base recommendations. It is however known that additional patient-controlled bolus doses by cPNB improve analgesia, allowing decreasing of the basal rate, opioid requirement, and their related side effects. Possible dose recommendations based on randomized controlled studies and clinical experience are given in Table 1:

Catheter location	Local anesthetic	Infusion rate
Interscalene	i. Ropi 0.2% ii. Ropi 0.3% iii. Bupi 0.125% (sufentanil 0.1 μg/ml and clonidine 1 μg/ml)	(i) CP: B: 4–6; Bo: 4–6; L: 20–30 (ii) CP: B: 3–5; Bo: 3-4; L: 20–30 (iii) CP: B: 5; Bo: 2.5; L: 30
Infraclavicular	(i) Ropi 0.2%	(i) CP: B: 4–6; Bo: 4–6; L: 20–60
Axillary	(i) Bupi 0.25%	(i) B: 10/B:0;Bo:10;L:60
Femoral (i) Hip Surgery (ii) Knee Surgery	(i) Hip (a) Ropi 0.2% (b) Bupi 0.125% (+sufentanil 0.1μg/ml and clonidine 1 μg/ml) (ii) Knee (a) Ropi 0.2% (b) Bupi 0.125% (clonidine 1μg/ml)	(i) Hip (a) B: 6; Bo: 4; L: 30 (b) B: 10 / B: 0; Bo: 10; L: 60 / B: 0; Bo 5; L: 30 (ii) Knee (a) CP: B: 3–6; Bo: 2–4; L: 20–30 min (b) B: 5; Bo: 2.5; L: 30
Fascia iliaca (knee surgery)	(i) Ropi 0.2%	(i) B:5;Bo:5;L:60/B:0;Bo:10;L:60
Subgluteal sciatic	(i) Ropi 0.2%	(i) B:5;Bo:5;L:60
Popliteal sciatic	(i) Ropi 0.2% (ii) Levobupi 0.125%	(i) CP: B:4–6; Bo: 4–6; L: 20 (ii) B: 5; Bo: 3; L:15

Table 1: Recommended doses of different local anesthetics for different catheter locations and their administration regimen according to clinical practice at the conducting clinic, publications or based on selected randomized controlled trials.
Ropi: Ropivacaine; Bupi: Bupivacaine; B: basal rate (ml/h); Bo: bolus (ml); L: lockout (min).

i. ANATOMICAL FUNDAMENTS

The brachial plexus is formed by the ventral rami of the lower four cervical (C_5, C_6, C_7, C_8) and the first thoracic nerve (Th_1).

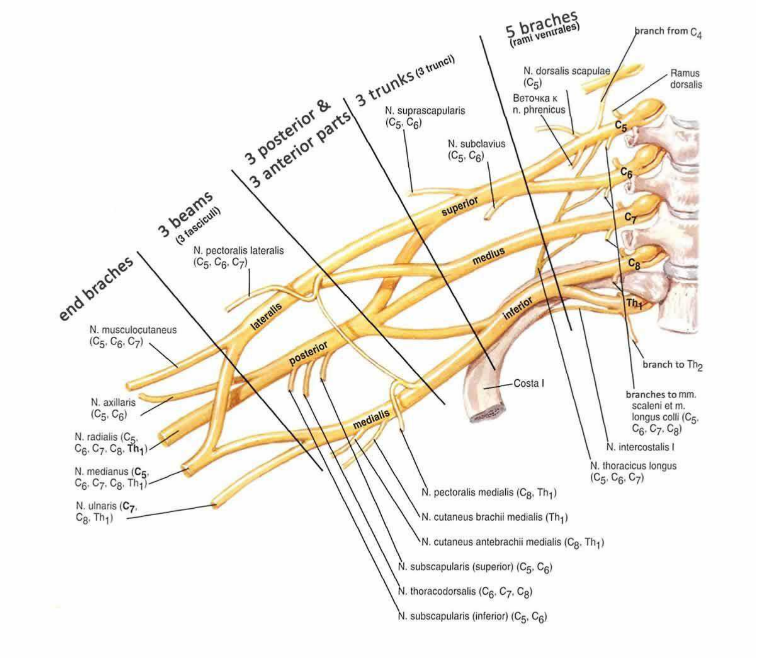

Figure 1
Plexus brachialis

In addition, few fibres of the second thoracic nerve (Th_2) may contribute to the plexus. The multiple intercommunications that are formed while passing from the interscalene cavity, between the anterior and the middle scalene muscle, distally until they end in the terminal nerves of the upper extremity further complicate the anatomical navigation.

For the correct placement is has been proven helpful to have an in-depth understanding of the anatomical pathway that these nerves are taking within the plexus. The three-dimensional arrangement of the trunks (superior, middle and inferior) and their implication in the muscle response, elicited during electro stimulation, are the key lead on which the anaesthesiologist relies on. An often-occurring pitfall is the insufficient blockage of the suprascapular nerve. This is due to the fact, that this nerve leaves the superior trunk very early.

The brachial plexus supplies all the motor and most of the sensory functions of the shoulder, except the cephalad-cutaneous part, which are innervated by the supraclavicular nerves. The three branches (medial, intermediate and lateral) originate from the lower part of the superficial cervical plexus (C_3,C_4). They supply sensory sensation of the shoulder in the region above the clavicle as well as the first two intercostal spaces anteriorly. Furthermore, they supply sensation to the posterior cervical triangle and the upper thorax as well as the forefront of the shoulder.

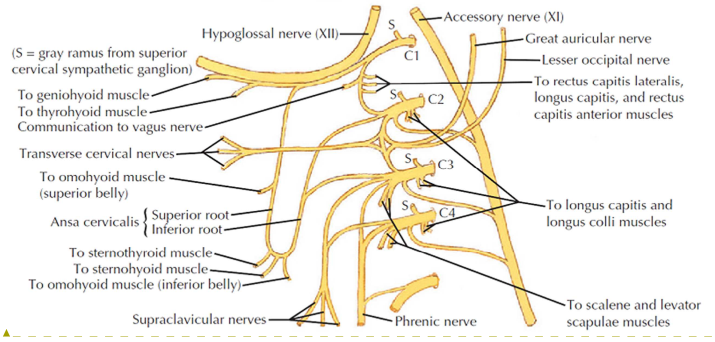

Figure 2
Plexus cervicalis

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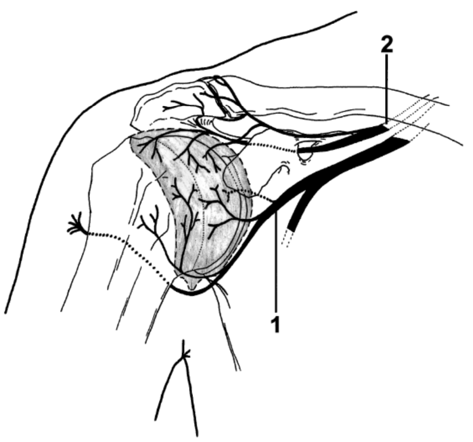
It is therefore essential, for either open or arthroscopic shoulder surgery in an awake patient, to block these supraclavicular nerves too to achieve a sufficient analgesia.

The shoulder joint as well has its distinctiveness regarding its innervation. The nerves supplying the ligaments, capsule and synovial membrane of the shoulder are fibres from the axillary, suprascapular and musculocutaneous nerve.[22] The share of contribution of each nerve varies often, so the innervation from the musculocutaneous nerve may be little to absent. Anteriorly, the suprascapular and axillary nerves mostly provide the innervation of the capsule and the glenohumeral joint. Alternatively, the musculocutaneous nerve may innervate the anterosuperior portion of the joint.



In regards of the superior supply, primary contribution

Figure 3. The innervation of the anterior part of the capsule and the glenohumeral joint: most contribution is given by the axillary (1) and the suprascapular (2) nerve.

comes from two branches of the suprascapular nerve, one branch supplying the acromioclavicular joint, the other reaching the posterior region of the joint. Again, some minor supply is provided by the axillary and the musculocutaneus nerves.

Posteriorly, the suprascapular nerve in the upper region and the axillary nerve in the lower region provide the main supply.

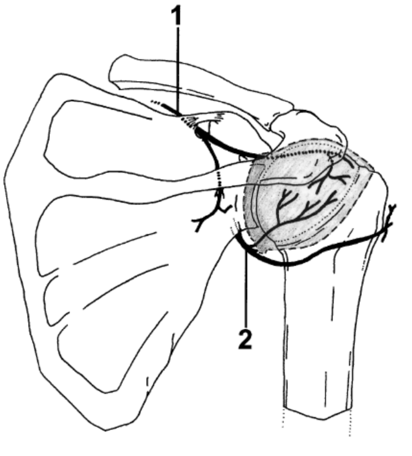


Figure 4. The innervation of the posterior portion is formed by the suprascapular (1) and axillary (2) nerve.

Inferiorly, the main nerve for the anterior region is the axillary nerve.

The brachial plexus communicates with the sympathetic trunk via gray rami communicates, which join the roots of the plexus. They are derived from the middle and inferior cervical sympathetic ganglia and the first thoracic sympathetic ganglion.

ii. LOCAL ANESTHETIC

The concept of local anesthesia is based on the blockage of nerve impulses to abolish sensation in the desired location. Local anesthetic, when applied in sufficient concentration and vicinity, prevent conduction of electrical impulses by the nerve membrane of axons by blocking voltage-gated sodium channels.

In myelinated nerves, such as large motor and sensory fibres, the axon is enclosed within many layers of a Schwann cell, which acts as an insulating sheath, protecting the axon from its surrounding and potential influencing ions. Therefore, the once released current is forced downward the axon and the conduction is sped up. The myelin sheath is only periodically interrupted by the Ranvier nodes, in which the impulse can be regenerated or modified. In the Ranvier nodes sodium channels, serving generation and propagation of impulses, are accumulated in high concentrations. In non-myelinated fibres such as autonomic postganglionic efferent and nociceptive afferent C fibres, the sodium channels are distributed in fewer numbers along the axon, resulting in a slower conduction as well as a lower responsiveness to local anesthetics.

A peripheral nerve consists of multiple bundles of axons, which are encased by different layers of connective tissue. So in order to reach the nerve axon's sodium channel, a local anesthetic must traverse multiple barriers before reaching the designated effect location.

Each peripheral nerve axon possesses its own cell membrane formatted mostly of phospholipids bilayers and membrane proteins. By distinctive permeability for certain ions, the membrane is able to maintain a voltage difference of -60 to -90mV, thus creating a concentration gradient for these ions. Being relatively impermeable to sodium ions but highly permeable to potassium ions, a higher potassium level intracellular is established. In addition the membrane contains multiple Na^+/K^+-pumps, which transport energy-dependent sodium outwards in exchange for a potassium uptake. The potassium uptake is the somewhat diminished by a passive leakage through potassium-leak channels.

Once equilibrium is reached, also called the steady state, an intracellular versus extracellular ratio of potassium of about 30:1 is established. According to the Nernst equation this ion concentration gradient results in a voltage potential:

$$E_m = \left(\frac{RxT}{F}\right) x \log\left(\frac{concentration_{extracellular}}{concentration_{intracellular}}\right)$$

R being the universal gas constant, T the absolute temperature constant and F the Faraday constant, remaining constant in all processes concerning the human body, the equation can be reformulated to:

$$E_m = -61mV \times \log \frac{concentration_{extracellular}}{concentration_{intracellular}}$$

Considering the normal ratio of potassium of about 120mmol/l in the intracellular space versus 4mmol/l extracellular, the equation is narrowed down to:

$$E_m = -61mV \times log(\frac{120}{4})$$

This equals the steady state potential of approximately -90mV. In case of an action potential conducted from a neighbouring cell, this negatively charged potential is changed towards the positive. Voltage-gated sodium channels located in the cell membrane open at around -50mV, resulting in a rapid sodium influx and therefore reverse the potential gradient over the membrane for a brief moment up to + 35mV. This builds the foundation for the next neighbouring cell to reach its excitability threshold.

Local anesthetics are able to block the voltage-gated sodium channels intracellularly, thus prohibiting the rapid cations influx and therefore the conduction of the action potential.

A typical local anesthetic is composed of a tertiary amine attached to an aromatic ring by an intermediate chain that contains either an ester or an amide linkage. This builds the foundation to classify currently clinically used local anesthetics in two groups: aminoesters and aminoamids. Their differences in chemical structure are accountable to their distinct effect, distribution and elimination.

All local anesthetics exist in solution in a very rapid chemical equilibrium between the uncharged base form and the cationic form. At a certain hydrogen ion concentration ($\log_{10}^{-1}$ (-pH)), specific for each local anesthetic, these two forms exist in equal quantities. The logarithm of this ion concentration is called the pKa value. Depending on this value, each drug's potency and acting duration varies.

Concerning the permeability of a local anesthetic across the membrane, two major principles have to be considered: only the base form is able to penetrate the hydrophobic cell membrane layers and the greater the lipophilic attributes of the local anesthetic, the easier the uptake in the desired tissue is accomplished. The onset of the effect is directly depended on the permeability of the drug. The activity duration is depending on the capability of the drug to stay at the desired location, which is altered by the local circulation and the amount of the drug that exists in a protein-unbound form. This applies for both classes of local anesthetics used today. However, in the elimination process subsists a distinctive difference: aminoamids are metabolized mainly by the hepatic cytochrome-P450-linked enzymes. Aminoesters are primarily metabolized by ubiquitous plasma cholinesterases (pseudocholinesterases), an enzyme found throughout the vascular system and in the cerebrospinal fluid. Because of the widespread occurrence of these enzymes, the plasma degradation of aminoesters is typically faster than of amide local anesthetics.

The greater the amount of local anesthetic is that is applied the higher its rate of toxicity. Toxicity can be observed locally as well as systemically. The systemic toxic effects involve mainly the heart (causing atrioventricular conduction blocks, arrhythmia as far as cardiac arrest) and the brain (including agitation, generalized central nervous depression or seizure). If hypoxemia or acidosis is present at the time of toxicity, these effects are aggravated. Therefore, prevention of intravascular injection or overdose is crucial in providing safe usage of local anesthetic.

iii. COMPLICATIONS

Even though the incidence of adverse effects is reported to be very low [23] and often only temporarily, there are specific complications involving the conduction of an interscalene cPNB.

Minor complications: These complications are frequently seen but in most cases transient during or immediately after the treatment has been completed:

I. Catheter obstruction or dislodgment, resulting in the need for an alternative analgesia concept
II. Leaking of fluid
III. Disconnection of the catheter to the pump
IV. Skin irritation or cutaneous allergic reaction due to the sterile dressing

Major complications:

I. Inaccurate catheter tip placement
    a. intravascular
    b. intrapleural
    c. intraneural
    d. epidural
    e. intrathecal
II. Phrenic nerve paralysis with decreases ipsilateral diaphragm function, causing mild hypercapnia and/or hypoxia.[24]
III. Infections: the reported rates for inpatients vary from 0% to 3.2% [25-27] and below 1% in outpatients.[28, 29] Risk factors being inappropriate antibiotic prophylaxis, admission to an intensive car unit, male sex, increased infusion duration and in some cases the site of catheter placement.[25]

IV. Neurological complications: Injury to the nerve may occur during the placement procedures or in the postoperative setting. The reported incidences range form 0%- 1.4% for interscalene catheter,[30] the majority resolving spontaneously within 3 months of surgery. It also needs to be mentioned that shoulder arthroplasty itself is associated with an estimated incidence of neurological complications in 1-4.3%.[31]

V. Local anesthetic toxicity: systemic anaesthetic toxicity is a serious but rare complication using cPNB. Although continuous infusions is unlikely to result in a sudden onset of toxicity, patient using also bolus treatment are at risk if the catheter dislocated intravascular.

iv. TECHNIQUES

In terms of placement techniques, many approaches have been reported over the years.

Winnie's approach: the lateral approach

The classical approach of Winnie [18] is performed at the level of the sixth cervical vertebrae. Its initial description involved the use of paresthesia for locating the proper placement.

The patient is placed in a dorsal recumbent position, the head turned opposite to the injection side. The landmarks utilized are the sternocleidomastoid muscle, its identification being simplified by asking the patient to elevate its head so the clavicle part is accentuated. The anterior scalene muscle is detected by placing the palpating finger laterally to this muscle. The fingers then should be rolled even more laterally until the interscalene groove is palpated. To determine the desired level of C_6, a horizontal line starting at the cricoid cartilage should be drawn.

With the index and middle finger of the adominant hand lying in the interscalene groove, a 22-gauge, 1.5-inch short bevel needle is inserted between them at the level of C_6. Winnie initially describe a direction of "perpendicular to the skins in all planes". Over time, this has proven to lead to more complications, since it does not take anatomical variations of different neck sizes into account. A direction slightly medial, dorsal and caudal should be chosen. The caudal direction is of utmost importance to avoid complications, as the transverse process will prevent an inadvertent puncture of the vertebral artery.[32] Winnie used, being at that times the standard procedure, the paresthesia method: the needle was then advanced until a paresthesia was elicited or the transverse process was encountered. Only paresthesia below the level of the shoulder was considered adequate. A more cephalad alteration in sensation could also been caused by the supraclavicular nerve branches.

Once the desired paresthesia was achieved, aspiration was carried out to identify blood or cerebral fluid and therefor detect misplacement. Then a volume of 20-30ml local anesthetic was injected, while closely monitoring the patient for signs of toxicity or inadvertent subarachnoidal injection.

With Winnie's technique over the years many complications have been reported: the most serious being total spine anesthesia, [33] epidural anesthesia,[25] as well as pneumothorax and intravasal injection into the vertebral artery.

Modified lateral technique of Meier:

In attempt to reduce the above-described complication, Meier *et al.* [34, 35] modified Winnie's approach by using the same landmarks, but inserting the needle 2-3cm cranial from cricoid cartilage. Furthermore, the needle is inserted in a 30-degree angle to the skin and then directed towards the passage of the middle to the lateral third of the clavicle, aiming at the puncture site of the classical insertion when using the vertical infraclavicular approach.

Modified lateral technique of Borgeat:

This technique represents another modification of the Winnie approach: it uses the same positioning and landmarks to identify the puncture site as described by Winnie. Special attention is paid to the palpation of the interscalene groove because it provides important information about its shape, depth, and course. Therefore the groove also is sketched before puncture. Then the needle is inserted close to the cricoid level (approximately 0.5cm below) at an angle between 45 and 60 degrees.

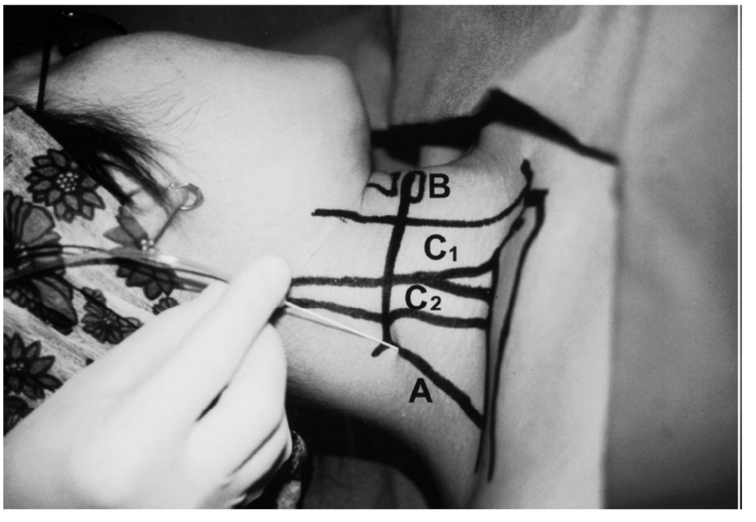


Figure 5

A 5cm, 22gauge short bevel needle (Stimuplex A, B.Braun Melsungen AG, Melsungen Germany) is used for placement, which is directed caudally and slightly lateral, or medial, according to the plane. The positioning of the needle is considered appropriate if the muscular twitches are still present with a current output below 0.4mA with an impulse-duration of 0.1ms.

This approach is suitable for both single-shot and continuous interscalene anesthesia/ analgesia.

A subcutaneous tunnelling of the catheter in cPNB is performed to prevent dislocation.[36]

Furthermore there have been attempts to introduce an approach from anteriorly and also posteriorly (posterior approach of Pippa). Both are not widely used and are considered to be inferior when compared to the lateral approach.

In the current investigation we applied the modified lateral approach by Borgeat.

III SCIENTIFIC RESEARCH QUESTION

The most often encountered muscular twitch when performing interscalene block is a biceps, a deltoid or proximal triceps response.

Regarding single shot infraclavicular block, recent studies have investigated the relation between the type of muscular response and the success rate.[37-39] They all demonstrated that a stimulation of the posterior cord, radial-type was associated with higher success rate compared to stimulation of the median or lateral cord.

To our knowledge no study has investigated if one or the other muscle response may influence the success rate of the interscalene block performed through the interscalene catheter. Therefore, we conducted a trial to compare the success rate of interscalene catheter associated with either a biceps or a deltoid and/or triceps response.

IV METHODE

After obtaining institutional ethics committee approval (Gesundheitsdirektion des Kantons Zürich, Kantonale Ethik-Kommission) and written informed consent, 300 consecutive adult patients of both sexes (classified as American Society of Anesthesiologists physical status I or II; age 18-65 yr; weight 50 - 95 kg) scheduled for an elective arthroscopic shoulder rotator cuff repair were entered in our study. Exclusion criteria were any contraindications to interscalene block, known allergy to Ropivacaine or opioids, and current analgesic treatment with opioids.

Patients were assigned according to a computerized randomization list into two groups:

Group B: biceps twitches

Group DT: deltoid and/or triceps twitches.

The assigned group determined the final chosen muscular response (either biceps or deltoid and/or triceps) to elicit for placement of the interscalene catheter (ISC). Inability to place the ISC was considered as an exclusion criterion during the study. The placement of the ISC was standardized for all patients. On the day of surgery, all patients were premedicated with 0.1 mg/kg midazolam given orally 1h before surgery. On the patients arrival in the induction room a 20 gauge intravenous catheter was inserted into a vein in the arm not requiring surgery. The interscalene brachial plexus using the modified lateral approach [40]was identified using a nerve stimulator (Stimuplex®, HNS 11; B. Braun Melsungen AG, Melsungen, Germany) connected to the proximal end of the metal inner of the stimulating needle (Polymedic®, 21 gauge stimulation needle; Te me na SAS, 78420 Carnières-sur-Seine, France).

In group B, placement of the needle was considered successful when a contraction of the biceps muscle vanished with a current output of exactly 0.3 mA. The impulse duration was 0.1 ms and the stimulation frequency 2Hz. In group DT, placement of the needle was considered successful when a contraction of the deltoid or proximal triceps muscle vanished exactly with the same neurostimulator settings as for group B (0.3 mA; 0.1 ms, 2 Hz).

In case of persistent muscle twitch below 0.3 mA, the needle was withdrawn or redirected until the muscle twitch vanished at exactly 0.3 mA. For the placement of the perineural catheter, the cannula-over-needle technique was used with a plastic cannula (Polymedic®, Polyplex N50-T, 20 gauge external diameter, Te me na SAS, 78420 Carnières-sur-Seine, France). The catheter (Polymedic®, Polyplex W50, 23 gauge with stylet, Te me na SAS, 78420 Carnières-sur-Seine, France) was introduced distally and advanced between the anterior and middle scalene muscles up to 2-3 cm past the tip of the stimulating needle. The catheter was subcutaneously tunnelled over 4-5 cm through an 18 gauge intravenous cannula in the direction of the opposite shoulder and fixed to the skin with transparent adhesive tape. Interscalene block was performed in all patients with 40 ml Ropivacaine 0.5% (200 mg) given through the catheter.

To maintain blinding, an anesthesiologist neither involved in the study nor aware of the patient's group assignment was responsible for the assessment of the block and the occurrence of acute complications (CNS or cardiac toxicity) and side effects (Horner syndrome and hoarseness). The block was considered successful when a sensory block (inability to recognize cold temperature in the territory of the axillary, radial and median nerve, pins-and-needles-type of paresthesia at the tip of the first and third finger), and a motor block (inability to abduct the arm and to extend or flex the forearm involving the axillary, radial and musculocutaneous nerves) were present within 30 min after the administration of the local anesthetic. Complete sensory blockade of the supraclavicular nerve (anterior and posterior skin territory of the shoulder) was also considered necessary for a successful block. When the block was complete, upon patient request sedation with Propofol using the target-controlled infusion technique (Diprifusor including the Marsh programme for Propofol, Graseby: Sims Graseby Limited Watford, Herts, United Kingdom) was allowed up to a maximum effect side concentration of 0.5 mcg/ml. Sedation was titrated to keep a Ramsay sedation score 2 (patient awake and relaxed). Block failure was defined as incomplete block of one or more of the axillary, radial and musculocutaneous nerves or inadequate extension of the block over the anterior or posterior shoulder or the need of supplementary analgesics (TCI Remifentanil including the Minto programme, Graseby: Sims Graseby Limited Watford, Herts, United Kingdom) because of pain in the operative field during surgery.

Postoperative analgesia was started six hours after the initial block (t = 0) with a patient controlled interscalene analgesia (Pain Management Provider, Abbott Laboratories, North Chicago, IL) with a baseline infusion of 8ml/h, a bolus dose of 5 ml with a lockout time of 20 min. Analgesia was performed with Ropivacaine 0.3% for the first 24 hours and then Ropivacaine 0.2% for the next 24 hours until the end of the study (t = 48). All patients received 2 g intravenous proparacetamol four times a day. Supplementary subcutaneous morphine (0.1 mg/kg) was available for rescue medication. The study was ended 48 h after start of the continuous infusion of Ropivacaine.

A research nurse not involved in the protocol was responsible for assessing the pain level twice a day by means of a visual analog scale (from 0 mm = no pain to 100 mm = worst pain imaginable) at rest and during shoulder mobilisation (passive abduction of the arm). The interscalene catheter was observed daily for signs of inflammation (redness or pain on pressure at the puncture site) or infection (presence of pus at the puncture site). All the patients were observed independently by a surgeon and an anaesthesiologist 6 weeks after surgery to perform a neurologic examination to assess neurologic complications, defined as any sensory-motor deficit impairing normal daily life or pain not directly related to the surgical procedure. The occurrence of one of these events was considered as a neurological complication.

V STATISTICAL ANALYSIS

According to results reported in the literature the success rate of the interscalene catheter varies by approximately 15% (between 80 to 95% success rate). Our hypothesis was that the deltoid and/or triceps response will provide a 5% higher success rate compared to the biceps response. Based on these data, a power analysis indicated that a sample size of 144 patients per group was sufficient to have an 80% power at the 95% significance level. To compensate for potential dropouts, we included150 patients per group. Demographic data were compared with the Mann-Whitney test and expressed as mean (SD). Success rate and side effects were analysed with the chi-square test. A $p<0.05$ was considered significant. For statistical analysis, the software SPSS for windows, version 11.5 (SPSS, Chicago, IL) was used.

VI RESULTS

Three hundred and three patients were consecutively enrolled in this prospective study. No difference was found among groups regarding demographic and surgical data. (Table 1)

Table 1. Patient and surgical characteristics

	Group D/T (N = 150)	**Group B (N = 150)**
Age (yr)	48 ± 15	53 ± 11
Gender (m/f)	102 / 48	111 / 39
Weight (kg)	76 ± 17	82 ± 18
Duration of surgery (min)	110 ± 52	104 ± 49

DT = deltoid/triceps; B = biceps.

The placement of the interscalene catheter was uneventful in 97.5%. One patient in group B and two in group D/T were not analysed due to inability to elicit the assigned muscular twitch. Two patients in each group needed a second puncture due to resistance during the catheter threading. One catheter in the group D/T was dislocated after 42 hours. No patient had to be excluded because of a technical problem with catheter placement.

In the D/T group a successful block was recorded in 148 patients, resulting in a success rate of 98.6% compared to 92.5% (139 patients) in the B group ($p < 0.05$) (Table 2).

In the D/T group, a deltoid response was observed in 42%, a triceps in 39%, a mixed response in 19% of all cases. In the D/T group two patients needed supplementary analgesics during handling of the posterior part of the shoulder capsule. Among these two patients one had a triceps response and one a deltoid response.

In the B group three patients had an incomplete radial block and received preoperative general anesthesia and seven patients needed supplementary analgesics during handling of the posterior part of the shoulder capsule.

Pain occurring during manipulation of the posterior part of the shoulder capsule was rapidly and effectively controlled using the application of Remifentanyl by TCI reaching effective site concentration of between 1.9 to 2.8 ng/ml.

Table 2. Success/Failure Rate N (%)

	Group D/T (N = 150)	**Group B (N = 150)**
Success rate	148 (98.6)*	139 (92.5)
Incomplete radial block	-	3
Incomplete post.extension to SCN	-	1 (0,7)[α]
Suppl. analgesics during surgery	1 (0,7)[α]	5 (3,4)
Suppl. analgesics during surgery and incomplete post.extension to SCN	1 (0.7)	2 (1,4)[α]

DT = deltoid/triceps; B = Biceps; post.: posterior; SCN: supraclavicular nerves; suppl.: supplementary

[α] Patients who had local infiltration at the posterior portal site.

*P < 0.02.

Local infiltration of the skin with 5 ml Lidocaine 1% at the posterior portal site was conducted in 1 and 3 patients in the D/T and B group, respectively.

In the postoperative setting, none of the patients with successful block during surgery needed supplementary opioids. Among the block failures who received already supplementary analgesics intraoperatively, 8 out of 10 patients needed supplementary morphine during mobilisation - but not at rest - between the start of mobilisation (t=24) until the end of the study (t=42). No supplementary morphine was needed in any patient during the last 6 hours of the study.

The occurrence of side effects was similar in the 2 groups (Table 3) and showed no statistical significance. No central nervous system or cardiac toxicity was assessed in either group.

Signs of inflammation or infection at the puncture site were not observed and at the scheduled examination 6 weeks postoperatively, no patient had sign or symptom of neuropathy.

Table 3. Side-effects/Complications N (%)

	Group D/T (N = 150)	**Group B (N = 150)**	
Horner syndrome	8 (5%)	12 (8%)	NS
Hoarseness	6 (4%)	8 (5%)	NS
Pain (local burning) during LA application	24 (16%)	30 (20%)	NS
Paresthesia during puncture	1 (0.5%)	0 (0%)	NS
CNS toxicity	0 (0%)	0 (0%)	NS
Cardiac toxicity	0 (0%)	0 (0%)	NS
Catheter infection	0 (0%)	0 (0%)	NS

DT = deltoid/triceps; B = biceps; LA = local anesthetic; CNS = central nervous system.

NS = non significant in statistical analysis

VII DISCUSSION

This study showed that for the placement of an ISC a deltoid and/or triceps was associated with a higher success rate compared to a biceps motor response. In the biceps group a higher incidence of incomplete radial nerve block was observed. There was no difference if either a deltoid, a triceps or a mixed muscle response of these two was obtained.

To avoid methodological bias, a specific surgical indication and technique - arthroscopic rotator cuff repair - was chosen and in all patients the tip of the stimulating needle was placed in the vicinity of the nerve to have a vanishing muscle response exactly at 0.3 mA and 0.1 ms.

We chose to compare these two types of muscular response because the former is associated with the antero-lateral part of the upper trunk and the latter with the posterior part.[41]

The results of this investigation are in accordance with those found after single shot coracoid infraclavicular block demonstrating a higher success rate after stimulation of the posterior cord. Lecamwasam et al[38] observed a 5.8% failure rate after posterior cord stimulation compared to 28.3% and 15.4% after lateral and medial cord stimulation, respectively. Using the same approach Minville *et al.[39]* noted that after blockade of the musculocutaneous nerve, subsequent injection on a radial response resulted in a more reliable success rate than injection with an ulnar or median response.

Is it possible to understand the lower failure rate after deltoid and/or triceps response? The interscalene space is surrounded by the prevertebral fascia, a firm, though membrane that lies in front of the prevertebral muscles, which extends sideways across the scalenus anterior, scalenus medius and levator scapulae muscles, getting thinner further out.[42] Considering the architecture of the upper trunk, the fibers going to shape the musculocutaneous nerve are located anterolateral,[41] it is then conceivable that the presence of this fascia - which may be very thin in some case - between the tip of the stimulating needle and the anterolateral part of the upper trunk will not prevent a twitch of a biceps despite a current as low as 0.3 mA. However, this situation will prevent a good spreading of the local anesthetics within the interscalene space, explaining the incomplete block of the radial nerve.

In cases of deltoid and/or triceps motor response this scenario is unlikely to occur since the fibers going to form these nerves are located on the posterior side of the upper trunk,[41, 43] making the possibility of having the fascia between the tip of the stimulating needle and the posterior part of the trunk very unlikely.

Nine patients (2 and 7 in the DT and B group, respectively) received supplementary analgesics (Remifentanil) during surgical manipulation of the posterior part of the shoulder capsule. This pain is most likely associated with an insufficient blockade of the lateral branch of the suprascapular nerve. The suprascapular nerve originates from the C_5 and C_6 nerve roots of the superior trunk, with a contribution from C_4 usually present as well. It provides sensation for a significant amount of the posterior shoulder capsule and may leave the upper trunk at different levels and sometimes very proximally.[44] It may then be difficult to block it in some patients, particularly those with a very short neck. In this trial 6 out of these 9 patients had a short neck, 2 and 4 in the DT and B group, respectively.

The block extension to the supraclavicular nerves was insufficient in 1 and 3 patients in group D/T and B, respectively. This event is easy to manage since subcutaneous infiltration with any local anesthetics at the arthroscopic portal puncture site will be sufficient to control pain during placement of the arthroscope. This problem can be explained by the location of this nerves, which is quite posterior and the remote from the application site. The presence of the median scalene muscle between the trunks and especially the lateral supraclavicular nerve can also hinder the diffusion of the local anesthetics.[44]

The incidence of acute or late complications was low and is in accordance with previous investigations.[23, 45] Postoperative analgesia was excellent (VAS<20) in all patients with successful blocks, confirming results from previous studies using patient-controlled interscalene analgesia.[14, 16] Among those who had insufficient suprascapular block 80% received supplementary morphine for mobilisation during the first 42 postoperative hours.

VIII CONCLUSION

In conclusion, this study showed that the stimulation of the posterior part (deltoid and/or triceps) of the upper trunk provided a significant higher and more reliable success rate compared to the anterior part (biceps). We therefore recommend the achievement, whenever possible, of a deltoid or triceps response for the placement of the interscalene catheter when using nerve stimulation.

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XI CURRICULUM VITAE

Sandra Esther Guzzella

13.06.1986	Geboren in Zürich ZH
1993-1999	Primarschule in Wallisellen, Zürich
1999-2003	Kantonsschule Oerlikon, Zürich
2003-2004	Schüleraustausch Columbus Ohio, US
2004-2005	Kantonsschule Oerlikon, Zürich
2005	Matura, Typ B, Zürich
2005-2012	Studium Humanmedizin an der Medizinischen Fakultät der Universität Zürich
2011-2014	freie wissenschaftliche Mitarbeiterin, Uniklinik Balgrist
2012	Eidgenössisches Examen Humanmedizin an der Universität Zürich
2013	Assistenzärztin Unfallchirurgie, Universitätsspital Zürich
2014	Research Fellow Anästhesiologie, Uniklinik Balgrist
2014- 2017	Assistenzärztin Anästhesiologie, Kantonspital Winterthur